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Hospital Volume Can Serve as a Surrogate for Surgeon Volume for Achieving Excellent Outcomes in Colorectal Resection

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Objective
To examine the association of surgeon and hospital case volumes with the short-term outcomes of in-hospital death, total hospital charges, and length of stay for resection of colorectal carcinoma.

Methods
The study design was a cross-sectional analysis of all adult patients who underwent resection for colorectal cancer using Maryland state discharge data from 1992 to 1996. Cases were divided into three groups based on annual surgeon case volume—low (≤5), medium (5 to 10), and high (>10)—and hospital volume—low (<40), medium (40 to 70), and high (≥70). Poisson and multiple linear regression analyses were used to identify differences in outcomes among volume groups while adjusting for variations in type of resections performed, cancer stage, patient comorbidities, urgency of admission, and patient demographic variables.

Results
During the 5-year period, 9739 resections were performed by 812 surgeons at 50 hospitals. The majority of surgeons (81%) and hospitals (58%) were in the low-volume group. The low-volume surgeons operated on 3461 of the 9739 total patients (36%) at an average rate of 1.8 cases per year. Higher surgeon volume was associated with significant improvement in all three outcomes (in-hospital death, length of stay, and cost). Medium-volume surgeons achieved results equivalent to high-volume surgeons when they operated in high- or medium-volume hospitals.

Conclusions
A skewed distribution of case volumes by surgeon was found in this study of patients who underwent resection for large bowel cancer in Maryland. The majority of these surgeons performed very few operations for colorectal cancer per year, whereas a minority performed >10 cases per year. Medium-volume surgeons achieved excellent outcomes similar to high-volume surgeons when operating in medium-volume or high-volume hospitals, but not in low-volume hospitals. The results of low-volume surgeons improved with increasing hospital volume but never equaled those of the high-volume surgeons.

Numerous studies have examined the association of surgeon case volume with clinical outcomes for various procedures and have shown higher surgeon volume to be associated with improved outcomes. This phenomenon has been described for an increasing number of procedures, including coronary artery bypass, angioplasty, gastrectomy, esophagectomy, thyroidectomy, arthroplasty, and aortic aneurysm repair.[1–8]

We and others have reported a similar relation between surgeon volume and improved clinical and economic outcomes for resections of colon and rectal cancer.[9–18] Our study showed that in-hospital death, length of stay, and total hospital charges were found to be significantly inversely related to surgeon volume, with the best results being achieved by the high-volume surgeon group who performed >10 cases per year.[9]

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Numerous studies have also shown that hospital volume has a similar association with clinical outcomes.[1,7,19–27] However, the possible interaction between surgeon and hospital volume has not been examined. This study examines the association and interaction of both surgeon and hospital volume with short-term outcomes in resections for colon and rectal cancer. Specifically, we examined whether hospital volume can provide improved outcomes for lower-volume surgeons.

It is important to identify the circumstances in which surgeons who do not perform a high volume of these procedures can nonetheless achieve excellent results. High surgical volume is clearly an important predictor of success, but there may be other subgroups of surgeons who are achieving excellent results. This study addresses whether hospital volume might be a surrogate for surgeon volume.

METHODS

Study Population

Outcomes of resection for colon and rectal carcinoma were examined using publicly available nonconfidential discharge data from nonfederal acute care hospitals collected by Maryland's Health Services Cost Review Commission during the calendar year period 1992 to 1996. The ICD-9-CM codes 153.0–154.1 (malignant neoplasm, stated or presumed primary, of the colon and rectum) were used to identify all adult (≥18 years old) patients with a primary diagnosis of colon or rectal cancer. From this group, patients who underwent colorectal resection as the primary procedure were identified by the ICD-9-CM codes 45.7 (partial colectomy), 45.8 (total colectomy), 48.5 (abdominoperineal resection), and 48.6 (other rectal resections including anterior resections).

The case mix variables examined were age, race, gender, primary payment source (Medicare, Medicaid, commercial), cancer stage (local involvement, nodal involvement, or organ metastasis), type of resection performed, patient comorbidities (an index score of 0 to 6 reflecting secondary diagnoses; based on the Dartmouth-Manitoba adaptation of the Charlson comorbidity index[28–30]), and urgency of admission (elective, urgent/emergent). Cancer stage was determined using the ICD-9 procedure codes in the secondary positions (196-196.9, nodal involvement; 197-198.89, organ metastasis). If a patient did not have either of these codes, it was assumed that the cancer was local.

Classification of Cases by Surgeon and Hospital Volume

Surgeons and hospitals were divided into three volume groups such that the surgical cases were approximately evenly distributed. Surgeon case volume groups were defined as low (≤5 cases per year), medium (5 to 10 cases per year), and high (>10 cases per year). Hospital case volume groups were defined as low (<40 cases per year), medium (40 to 70 cases per year), and high (≥70 cases per year). Each study case was categorized according to surgeon and hospital mean annual case volume.

Outcomes

Three outcomes were examined: in-hospital death, total hospital charges, and length of stay. Hospital charges were adjusted for inflation to 1996 dollars using the Health Care Financing Administration Input Price Indices.[31] Hospital charges are strictly regulated in Maryland and serve as a reasonable proxy for actual costs. The average cost-to-charge ratio in Maryland hospitals is approximately 0.75.[32]

Statistical Analysis

The distribution of case mix variables in each of the volume groups was compared using analysis of variance for the continuous variables and the chi square statistic for categorical variables. Bivariate analysis was used to determine which case mix variables were associated with each of the three outcomes. Based on these analyses, regression analysis was then used to model the association between the volume groups and outcomes, adjusting for variations in case mix. Multiple linear regression was used to model the continuous outcomes of length of stay and total hospital charges. Because of the skewed distribution of both outcomes, a natural log transformation was performed to achieve a more normal distribution for the analysis. Adjusted predicted outcomes for each of the volume groups were calculated from the models using the population case mix means and then exponentially transformed back to their original scales. Poisson regression was used to model the binary outcome of in-hospital death. Such analysis is often used in epidemiologic studies when event rates (*i.e.*, deaths) are low, and it allows a direct estimation of relative risk for death.

To assess the interaction of surgeon and hospital volume, the groups were further subdivided into nine groups according to both surgeon and hospital volume (a 3×3 matrix), and the same regression analysis was performed.

Two-tailed tests were used for all analyses, and statistical significance was set at $p < 0.05$. Statistical analysis was performed using STATA 5.0 software (STATA Corp., College Station, TX).

RESULTS

Population Case Mix

During the 5-year study period, 812 surgeons at 50 hospitals performed 9739 resections for colon and rectal cancer. Table 1 summarizes the volume groups. The study population had a mean age of 69.2 years. Patients were equally distributed by gender (48% men, 52% women). Patients

Table 1. SUMMARY OF VOLUME GROUPS

	Total	Low	Medium	High
Surgeons				
Definition of group		≤5	5 to 10	>10
No. of surgeons	812	661	113	38
		81%	14%	6%
No. of cases	9739	3464	3626	2649
		36%	37%	27%
Average annual case volume	3.1	1.8	7.0	14.0
Hospitals				
Definition of group		<40	40 to 70	≥70
No. of hospitals	50	29	14	7
		58%	28%	14%
No. of cases	9739	3110	3484	3145
		32%	36%	32%
Average annual case volume	39	21.5	50.0	89.9

were predominantly white (80.5%) and mostly Medicare recipients (64.9%). Most patients had few other significant comorbidities (mean index score 0.42 on a scale of 0 to 6). More than half (57.5%) had only local involvement, 19.9% had nodal involvement, and 22.5% had organ metastasis. More than half (57.4%) were classified as elective cases; 42.2% were urgent. Colectomy was performed in 81.3%; 18.7% underwent a rectal resection. Table 2 summarizes the population case mix by surgeon and hospital volume groups.

Surgeon and Hospital Volume Group Characteristics

The majority of surgeons and hospitals were in the low-volume groups. In the low-volume surgeon group, 661 surgeons (81%) performed 3461 cases (36%), at an average rate of 1.8 cases per year. In fact, 373 surgeons (46%) performed an average of only one case or less per year. In the medium-volume surgeon group, 113 surgeons (14%) performed 3626 cases (37%), at an average rate of 7.0 cases per year. In the high-volume surgeon group, 38 surgeons (5%) performed 2649 cases (27%), at an average rate of 14.0 cases per year. There were significant differences in case mix between the surgeon volume groups in all case mix variables except for gender and the comorbidity score. In general, higher-volume surgeons saw slightly older patients, more white patients, fewer Medicaid patients, more elective cases, and cases with less metastatic disease and performed a greater proportion of rectal resections.

In the low-volume hospital group, 3110 cases (32%) were performed at 29 hospitals (58%), at an average rate of 21.5

Table 2. SUMMARY OF PATIENT CHARACTERISTICS BY VOLUME GROUPS

		Surgeon Volume Groups				Hospital Volume Groups			
Characteristics	State Total	Low	Medium	High	p*	Low	Medium	High	p*
Mean age (years)	69.2	68.7	69.2	69.3	<0.01	69.1	69.5	68.8	NS
(SD)	(12.4)	(12.7)	(12.3)	(12.3)		(12.4)	(12.5)	(12.4)	
Gender (% male)	47.6	47.0	48.6	47.2	NS	47.8	46.6	48.7	NS
Race									
% White	80.5	74.4	83.8	84.1	<0.01	74.9	81.7	84.7	<0.01
% Black	17.7	23.8	14.8	13.7		23.3	16.5	13.5	
Mean comorbidity score	0.42	0.43	0.42	0.41	NS	0.45	0.43	0.39	<0.01
(SD)	(0.71)	(0.74)	(0.71)	(0.67)		(0.73)	(0.72)	(0.67)	
Tumor progression									
% Local	57.5	56.8	57.0	59.3	0.03	56.6	59.2	56.6	<0.01
% Nodal involvement	19.9	19.4	20.0	20.4		18.7	21.0	19.9	
% Organ metastasis	22.6	23.9	23.0	20.4		24.7	19.8	23.6	
Procedure									
% Partial colectomy	80.1	83.8	80.5	74.7	<0.01	82.7	81.7	75.7	<0.01
% Total colectomy	1.2	1.2	1.2	1.1		1.2	0.9	1.4	
% Abdominoperineal resection	7.0	6.7	6.9	7.7		5.9	6.3	9.1	
% Other rectal resection	11.7	8.3	11.5	16.5		10.3	11.2	13.8	
Admission status									
% Elective	57.4	53.6	58.5	60.8	<0.01	47.5	63.7	60.2	<0.01
% Urgent/emergent	42.2	46.0	41.1	38.8		51.6	36.0	39.8	
Payor									
% Commercial	30.1	30.1	30.6	29.6	<0.01	28.2	29.1	33.2	<0.01
% Medicare	64.9	63.2	65.3	66.6		64.2	66.7	63.6	
% Medicaid	2.8	4.1	2.1	2.0		4.0	2.8	1.7	

* p Values reflect comparisons within surgeon or hospital volume groups. Chi square test for categorical variables, analysis of variance for continuous variables (age and comorbidity score).

Table 3. SUMMARY OF CRUDE AND CASE MIX-ADJUSTED OUTCOMES BY VOLUME GROUPS

Characteristics	State Total	Surgeon Volume Groups			Hospital Volume Groups		
		Low	Medium	High	Low	Medium	High
Mortality							
Crude (%)	3.5	4.5	3.3	2.6	4.7	3.0	3.0
Adjusted relative risk		1.00	0.79†	0.64*,§	1.00	0.79†	0.78†,§
Total hospital charges							
Crude ($)	15142	16,884	14,369	13,923	16,896	14,496	14,035
Adjusted ($)		13,025	11,735*	11,642*,§	12,583	12,111*	11,784*,‡
Length of stay							
Crude (d)	11.5	12.6	11.2	10.7	12.7	11.2	10.8
Adjusted (d)		10.1	9.5*	9*,‡	9.7	9.6†	9.3*,‡

p values in comparison with the corresponding low-volume group: *$p < 0.01$; †$p < 0.10$; p values in comparison with the corresponding medium-volume group: ‡$p < 0.05$; §p = NS.

cases per year. In the medium-volume hospital group, 3484 cases (36%) were performed at 14 hospitals (28%), at an average rate of 50.0 cases per year. In the high-volume hospital group, 3145 cases (32%) were performed at 7 hospitals (14%), at an average rate of 89.9 cases per year. There were similar statistically significant differences in case mix between the hospital volume groups in all case mix variables except for age and gender. In general, higher-volume hospitals saw more white patients, patients with a lower comorbidity score, fewer Medicaid recipients, more elective cases, and a greater proportion of rectal resections.

Surgeon Volume Effect

Increased surgeon case volume was associated with improvement in all three outcome measures (Table 3). After adjusting for case mix, the risk of in-hospital death was reduced by 36% in the high-volume surgeon group compared with the low-volume surgeon group ($p < 0.01$). There was also a trend toward a reduced mortality rate in comparison with the medium-volume surgeon group, although these comparisons were not statistically significant. The case mix-adjusted average total charges were significantly reduced in both the medium-volume ($11,735) and high-volume ($11,642) surgeon groups compared with the low-volume group ($13,025) ($p < 0.01$ for both comparisons). There was no charge difference between the medium- and high-volume surgeon groups. The case mix-adjusted length of stay was reduced in the medium-volume (9.5 days) and high-volume (9.0 days) groups compared with the low-volume group (10.1 days) ($p < 0.01$ for both comparisons). The length of stay for the high-volume group was also statistically significantly reduced compared with the medium group ($p < 0.01$).

Hospital Volume Effect

Increased hospital case volume was also associated with improvement in all three outcomes independent of surgeon case volume (see Table 3). Although a reduced mortality rate was observed at medium- and high-volume hospitals compared with low-volume hospitals, these differences were not statistically significant. The case mix-adjusted average total charges were significantly reduced in both the medium-volume ($12,111) and high-volume ($11,784) hospital groups compared with the low-volume group ($12,583) ($p < 0.01$ for both comparisons). The charge difference between the high- and medium-volume groups was also statistically significant ($p = 0.04$). The case mix-adjusted length of stay was reduced in the high-volume group (9.3 days) compared with the low-volume group (9.7 days) ($p < 0.01$). The high-volume group was also statistically significantly reduced compared with the medium-volume group ($p = 0.01$).

Interaction of Surgeon and Hospital Volume

The results of this analysis are shown on Table 4 and Figure 1. High-volume surgeons had a lower adjusted relative risk of death in all hospital settings (high, 0.58; medium, 0.53; low, 0.63) than low-volume surgeons (high, 0.8; medium, 0.87; low, 1.0). In contrast, medium-volume surgeons had mortality rates that depended on the hospital setting. At high-volume hospitals, their ARR was 0.54, which was as good as that of high-volume surgeons. However, at low-volume hospitals their adjusted relative risk of death was 0.99, identical to that of low-volume surgeons. The pattern of results for the other outcome parameters was similar.

Other Important Independent Variables

Besides surgeon and hospital volume, other independent variables had a significant impact on the regression models. For all three outcomes, an emergent or urgent admission, increased age, presence of organ metastasis, increased co-

Table 4. INTERACTION OF SURGEON AND HOSPITAL VOLUME

	Hospital Volume Groups		
Surgeon Volume Groups	**Low**	**Medium**	**High**
Low n	1397	1171	896
Crude mortality (%)	5.08	3.84	4.35
Adjusted relative risk	1	0.87†	0.93†
Average total charges ($)	18118	15849	16315
Adjusted total charges ($)	13507	12956*	12630*
Average length of stay (d)	13.1	12.2	12.3
Adjusted length of stay (d)	10.1	10.3†	9.9†
Medium n	1000	1508	1118
Crude mortality (%)	4.90	2.92	2.42
Adjusted relative risk	0.99†	0.66*	0.54*
Average total charges ($)	16121	14145	13104
Adjusted total charges ($)	12412*	11689*	11175*
Average length of stay (d)	11.9	11.1	10.5
Adjusted length of stay (d)	9.6*	9.7*	9.1*
High n	713	805	1131
Crude mortality (%)	3.51	2.11	2.39
Adjusted relative risk	0.63	0.53	0.58
Average total charges ($)	15983	13186	13149
Adjusted total charges ($)	11658	11652	11497
Average length of stay (d)	12.8	9.7	10
Adjusted length of stay (d)	9.4	8.6	8.9

p values in comparison to low-volume surgeons at low-volume hospitals: *$p < 0.05$; †p = NS.

morbidity index, male gender, undergoing a total colectomy, and Medicaid payer status were associated with poorer outcomes. Also, nonwhite race, undergoing a rectal resection, and Medicare payer status were also associated with increased charges. Black race, undergoing an abdominoperineal resection, and Medicare payer status were also associated with increased length of stay. Regression model results for nonvolume independent variables are shown in Table 5.

DISCUSSION

This study examined surgical practice patterns for the cohort of patients who underwent resection for colorectal cancer in Maryland during the 5-year study period. The results identify a positive relation between high individual surgeon case volume and favorable outcomes. This positive association has been identified previously for colorectal surgery as well as for numerous other surgical procedures. The analysis was carried further to probe the influence of hospital case volume on outcomes and to evaluate the interaction between individual surgeon case volume and hospital case volume. The findings confirmed our hypothesis that hospital case volume could serve as a surrogate for individual surgical case volume in improving outcomes. Surgeons in the medium-volume group who worked in higher-volume hospitals had results indistinguishable from the best group results of high-volume surgeons; however, in lower-volume hospitals, these medium-volume surgeons had poorer results than the high-volume group.

Another focus in this study was analysis of the distribution of surgical cases among surgeons and hospitals. From an outcome viewpoint, it would be desirable to have the majority of cases performed by higher-volume surgeons in higher-volume hospitals. Benefits of such regionalization have been shown in this state for pancreatic surgery.[21] However, in reality the vast majority of surgeons in this study (81%) were in the low-volume group (≤5 cases per year), performing an average of 1.8 cases per year. The majority of hospitals (58%) also were in the low-volume group (<40 cases per year), performing an average of 21.5 cases per year. This is not unique to Maryland: similar widely skewed practice patterns in colorectal surgery have also been found in several other studies.[1,6,10–18] Such a distribution is a concern in light of accumulating evidence about the association of volume and outcomes.

Previous studies in colorectal surgery have clearly shown wide variations in mortality and morbidity rates among individual surgeons.[10–18] One of the surgeon-specific factors identified as associated with outcomes in some but not all of the studies was surgeon case volume. Specialty training or interest has been shown to correlate with improved outcomes in several studies.[17] In similar fashion, hospital volume has also been associated with outcomes, as reported in this and other similar studies.

That increased volume would lead to improved outcomes is both intuitive and plausible. It would be expected that the more experienced surgeons would have greater expertise and thus would produce better outcomes. Individual case volume is a natural measure for surgeon experience. Another possible interpretation that has been raised is a selection bias in referral patterns. Surgeons known to have better outcomes would be more likely to receive patient referrals, contributing to increased volume. This was shown at the hospital level by Luft et al,[24] who showed that hospitals with poorer outcomes attract fewer admissions for several surgical procedures, including colon surgery.

The hospital-specific factors related to outcomes are un-

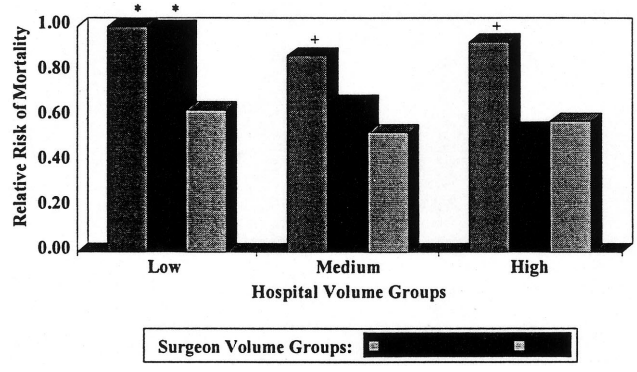

Figure 1. Mortality rate by surgeon and hospital volume. *, $p<0.5$; +, $p\leq0.10$ compared to high volume surgeons at high-volume hospitals.

Table 5. REGRESSION MODEL RESULTS FOR NONVOLUME INDEPENDENT VARIABLES*

Variable	Mortality (Relative Risk)	Total Charges (ln Coefficient)	Length of Stay (ln Coefficient)
Urgent/emergent admission	2.88†	0.358†	0.409†
Age	1.05†	0.008†	0.008†
Female sex	0.75†	−0.059†	−0.028†
Race			
Black	0.93	0.178†	0.112†
Nonwhite/nonblack	0.43	0.101‡	0.054
Procedure			
Total colectomy	2.18‡	0.438†	0.291†
Abdominoperineal resection	0.78	0.295†	0.226†
Low anterior and other rectal resections	0.86	0.109†	0.019
Tumor stage			
Nodal involvement	0.73§	−0.003	−0.004
Organ metastasis	1.75†	0.133†	0.105†
Comorbidity index	1.32†	0.092†	0.051†
Payment source			
Medicare	1.37	0.069†	0.069†
Medicaid	2.06‡	0.174†	0.137†

* The reference groups for categorical variables were elective admission, male sex, white race, partial colectomy procedure, local involvement only tumor stage, and commercial payment source.
† $p < 0.01$
‡ $p < 0.05$
§ $p < 0.10$

doubtedly multifactorial. Higher hospital volume allows for more specialized teams in all aspects of patient care and the development of clinical pathways. Anesthesiologists are often more familiar with higher-risk patients. Surgical intensive care units are often more developed. The availability of other expert colleagues, both surgical and medical, facilitates discussion and assistance in diagnosis, techniques, and perioperative patient care. Physical resources can be more effectively and efficiently distributed, contributing to lower costs. The administrative workload of higher volumes necessitates focused social work and discharge planning teams.

We considered the possibility that the groupings by case volume may be too selective and that there may be subgroups of the lower-volume surgeons who are still able to achieve excellent outcomes. For example, surgeons who perform a low volume of colorectal surgery but a large number of other gastrointestinal surgeries would likely perform better than surgeons who performed a lower volume overall. However, we found that few surgeons actually fall into this category; in general, surgeons who perform higher volumes of colon and rectal surgery are the same surgeons who perform higher volumes of other gastrointestinal surgeries. One subgroup of surgeons who did show improved outcomes was the lower-volume surgeons at higher-volume hospitals. Surprisingly, the magnitude of the improvement was such that medium-volume surgeons at medium- or high-volume hospitals were able to achieve results similar to those of high-volume surgeons.

The incremental in-hospital mortality rate and charges observed with the current surgical outcome results, as opposed to those that would be achieved if all cases were done with the outcomes of the high-volume surgeons, can be calculated (Table 6). If high-volume surgical outcomes could have been achieved during the period of the study, 92 in-hospital deaths and $5,128,000 of charges would have been saved in Maryland. Assuming that a similar mix of surgeons and hospitals were achieving similar results throughout the United States, the savings of a best group scenario compared with the present case mix would be 4968 in-hospital deaths and $276,912,000 in charges. The reasons for this are likely secondary to the hospital-specific factors mentioned above. These findings have significant implications for health care policy.

Surgeon and hospital case volumes were not the only variables significantly associated with outcomes or even the most important ones. Multivariate regression was used to rank the variables according to their strength of association with outcome. Urgent or emergent admission, increased age, male sex, presence of metastatic disease, increased comorbidities, undergoing a total colectomy or rectal resection, black race, and Medicaid status were significantly associated with worse outcomes. The importance of these variables has been demonstrated in several other studies, supporting the robustness of our models.

Coding error is frequently listed as a limitation of studies using hospital discharge summary databases. Green et al[33] showed that substantial interhospital coding variations exist, particularly in the underreporting of comorbidities and distinctions between urgent and emergent admissions. They

Table 6. POTENTIAL MORTALITY AND CHARGE DIFFERENTIAL USING GENERALIZED HIGH-VOLUME SURGEON OUTCOMES

	Cases	Charges	Total (×1000)	Mortality Rate	Deaths
Current					
Low	3464	$13,025	$ 45,119	4.5%	156
Medium	3626	$11,735	$ 42,551	3.3%	120
Total			$ 87,670	2.6%	276
Best	7090	$11,642	$ 82,542	2.6%	184
Maryland differential			$ 5,128		92
United States (Maryland population × 54)			$276,912		4968

also reported a 9% error rate in the coding of the principal diagnosis. Several changes have occurred since then, with marked improvement in coding accuracy.[28] These include peer review coding audits, Medicare-mandated expansion of the number of spaces for secondary diagnoses, and more precise definitions. For this study, urgent and emergent admissions were grouped together. To protect against isolated coding errors of principal diagnosis, cases were selected by both a principal diagnosis of primary colon or rectal cancer and by a principal procedure of colorectal resection.

It is clear that both surgeon and hospital volume are significant factors in determining results for resection of colon and rectal cancer. Practice patterns of Maryland surgeons show a very skewed distribution toward low-volume surgeons. An understanding of the clinical biology of the volume–outcome relation needs to be addressed. The details of the specific mechanism by which increased experience improves outcomes need to be identified and incorporated into the practice of all general surgeons.

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Discussion

DR. MURRAY F. BRENNAN (New York, New York): I would like to thank Dr. Harmon for asking me to comment and appreciate the opportunity to review the manuscript ahead of time.

The observation that increasing volume translates into improved survival and decreased length of stay is not surprising. The authors emphasize, however, that 812 surgeons at 50 hospitals performed 9,739 resections. The majority of surgeons and hospitals were in the low-volume group; 81% of surgeons performed an average of 1.8 cases per year. The majority of us here today would prefer we not be one of those two cases, and if we were, to pay more for the privilege!

The authors' important contribution, however, is that they try to examine "how few is enough." May I have my one slide? This shows the New York City Cancer Mortality Operative Statistics for 1997, a single year, based on 53,834 cases performed in the operating rooms of New York City. It is clear that mortality, on the vertical axis, declines as case volume increases. More importantly, it appears that in high-volume institutions, the low mortality is reached between five and ten cases per surgeon, whereas in other institutions the low mortality is only reached at 30 cases. This would suggest, as Dr. Harmon has implied, that in a high-volume institution the number of cases required for the lowest mortality may be less than that seen in a low-volume hospital. In addition, on this slide we illustrate that over 65% of cases in our institution are performed by surgeons who perform more than 40 of those procedures a year. This is in contradistinction to other institutions where only 12% are performed by surgeons who do more than 30 a year.

The question then is: How many is enough? The data such as in this slide and Dr. Harmon's data are known to state regulatory agencies and available to third-party carriers. Are we then, Dr. Harmon, ready to make suggestions as to what is the minimum number of single procedures to be done by a surgeon in 1 year? Or should we wait until regulatory agencies and/or payers make that decision for us?

This is a very highly charged issue. It will require leadership by this profession, as it should not be left to the legislators. The Institute of Medicine just a few days ago published guidelines for complicated cancer care. I ask: Are we ready to do the same? I very much appreciate the chance to comment.

PRESENTER DR. JOHN W. HARMON (Baltimore, Maryland): Thank you, Dr. Brennan. Your question is provocative. Clearly ten procedures per year is enough. And if you are in the hospital that is doing at least 70 cases per year, then surgeons performing just five cases per year can get the best results that we observed. So that is a note for optimism.

There are a couple of things that are interesting that can be mentioned here. That is that just a handful of talented surgeons, 39 surgeons, are driving the excellent results in the state of Maryland. And the results of these surgeons are not hospital-dependent. They are not getting their good results just because they are operating in a place with a care map or something like this. They get these good results in little hospitals and medium hospitals, not just large hospitals. Wherever they are, that group is doing just fine, thank you. And the referral system is referring a full third of the cases in the state of Maryland to those 39 surgeons. So these doctors that are making referrals are making a good judgment in that regard. So that is where the room for optimism is.

DR. JOSEF F. FISCHER (Cincinnati, Ohio): I would like to thank Dr. Harmon for giving me the manuscript in enough time to review it. It is very interesting, and as Dr. Brennan has already suggested, a provocative manuscript.

This study suggests to me three things. First, that surgeons who do what are defined as a medium-level volume may in fact achieve results as good as high-volume surgeons. Secondly, that in some way as yet to be defined, the generalized hospital community expertise in a high-volume hospital may osmose into a medium-volume surgeon to achieve the same results. And third, most interesting to me, is that the high-volume surgeons have as good outcomes in low-volume hospitals as they do as in high-volume hospitals, something which is in the manuscript and in the slides but which was not emphasized. I have five questions of you, Dr. Harmon.

First, what is the working hypothesis? What is it about colon resection that a high-volume hospital has that a low-volume hospital does not? After all, for the most part these are straightforward procedures, at least to most of the people in this room. Does this segregate itself to the low anterior resections or to the abdominal peritoneal resections, which according to your retrieval of information you should have been able to segregate?

Second, this is the second paper I know that really covers this phenomenon, the first being Dr. Brennan's about pancreaticoduodenectomy, if I recall correctly, that shows that what are called medium-volume surgeons can do as well as high-volume surgeons under certain circumstances. In this paper, it is proposed that this be the hospital. I don't recall that in Dr. Brennan's paper, although I may be wrong. And I just wonder about the arbitrary nature of setting low and medium. How much is enough, as Dr. Brennan has said. It seems to me that from his paper on pancreaticoduodenectomy and your own data, one might argue that five colon resections a year is enough to maintain proficiency. Do you have any thoughts on that?

Third, is this the phenomenon of high-volume surgeons doing as well in a low-volume hospital? It is clear from your data, and you

mentioned it in your response to Dr. Brennan's question. What is that about? My own prejudice is that there are multiple components in outcome, among which are the skill of the surgeon and the environment in which the surgeon operates, and perhaps some other arbitrary factors.

Fourth, length of stay: I realize that this is 1992 to 1996. But the length of stay seems abnormally long, in fact 10 days, even in the high-volume surgeons. Do you have any thoughts about that? Was there a trend towards the end of the study or subsequent data that suggests that the length of stay is coming down, particularly in the high-volume surgeons?

DR. HARMON: Thank you, Dr. Fischer. First is the difference between the low- and the high-volume hospitals and why the surgeons do better in the high-volume hospitals. Some things that come to mind would be care maps that would be available, the team approach, the SICU. Another thing would be surgeon-to-surgeon consults, a culture of excellence.

Regarding the different surgical procedures, we did expect to see that the low-volume surgeons would have a particular problem with low anterior resections or APRs. It didn't come out of the data. That is all I can say.

The difference between this study and the pancreas results that have been reported by Dr. Cameron from Hopkins and Dr. Brennan from Sloan-Kettering, is that with pancreas surgery you have a preponderance of cases in one hospital, where you have a culture of excellence. It is a bit different from colon surgery, which is done in many places. I think there were seven centers just in the state of Maryland that were high-volume.

Why are the results so good in the high-volume hospitals? It may be that capable surgeons are drawn to the high-volume hospitals.

Finally, the length of stay I agree is a bit long. This number was from the period 1992 to 1996. I think if we were to do it right now, it would be shorter.

DR. MICHAEL J. ZINNER (Boston, Massachusetts): I would like to thank Dr. Harmon for the opportunity to comment on this important work. It is topical, valuable, and well done. The group from Hopkins has made significant contributions to the field by highlighting the important relationships between procedure-related volumes and outcomes.

In this study they seek to examine the association between surgeon and hospital volumes—specifically, they seek to prove that hospital volume is a surrogate for surgeon volume. I think you have proven very well that the outcome is related to surgeon volume in the data you presented. And this is not surprising. In colorectal surgery, that has been shown by others. Porter, for example, showed that just doing three cases a year would improve outcome.

But what was surprising was that 80% of the surgeons in this group did less than two cases per year. Who are those surgeons? It seems to be at odds with the data we have seen from Dr. Ritchie, which looked at the number of colectomies done by people recertifying for the American Board of Surgery, and that is an average of 15 cases per year. So again, who are those people?

What is also a little surprising is that there is a relationship between hospital volume and colorectal outcomes. One study I know of colorectal surgery was a study from the German Study Group on Colorectal Carcinoma looking at 2,300 cases, and they did not find a relationship between hospital volume and outcome.

If I read your data correctly, in the abstract it says that low-volume surgeons at high-volume hospitals do worse (with a 0.93 risk of death) than high-volume surgeons at low-volume hospitals (a 0.63 incidence of death). That is, it looks like it is still surgeon volume-dependent and not as much hospital-dependent. So perhaps we could conclude that hospital volume augments the surgeon effort, but I can't conclude that it is a substitute for it.

Could you also comment on the length of stay at your institution? My comments about length of stay are similar to Dr. Fischer's in that yours seem to be about 30% or 40% higher than some of the other regions in the country. Dr. Warshaw and I have had an opportunity recently to look at our own in our region and found that the MGH and the Brigham had postop lengths of stay between 5.1 and 6.3 days, and in our region it runs about 5 to 7 days.

I would like to thank you again for allowing me to review this important abstract and I think we are going to be seeing more of this data in the future.

DR. HARMON: Our length of stay is also down in the range you describe. I am just surprised that it had not gotten down for the whole state in the 1990s.

Dr. Zinner raises the issue of the hospital volume *versus* surgeon volume. For certain kinds of operations, including pancreatic resection and cardiac surgery, hospital volume has been shown to have a huge impact. For these cases to go well, a team seems to be necessary. Thyroid surgery was evaluated by Drs. Udelsman and Sosa in our group at Hopkins and they didn't find a hospital effect at all. This is entirely surgeon-dependent. With the recurrent laryngeal nerve, the surgeon either cuts it or doesn't. So it is totally a surgeon issue. Colorectal, I think, is more surgeon-dependent. As you can see, the high-volume surgeons did just fine in the low-volume hospitals. The talent of the surgeon is paramount here.

Dr. Zinner's final question: Who are these surgeons who are doing so few cases? Well, we tried to address this. The next thing we might do with this database is really evaluate that.

Some of these low-volume surgeons are OB/GYNs or urologists who unexpectedly encounter a colon cancer. We found that. Some of these are transient people who have just arrived in town or are leaving, so they have a very low volume. But the vast majority of them seem to be surgeons who are covering emergency rooms, and just get very few colon cases during the course of a period of time.

DR. JONATHAN E. RHOADS (Philadelphia, Pennsylvania): In light of our president's address, it occurs to me that house staff might be a factor and in hospitals with low volume, there might be no residents and the patients might be covered by nurses a good part of the time. So I would like to ask whether the presence or absence of resident programs had been looked at, and whether it was a factor.

DR. HARMON: Thank you, Dr. Rhoads. That is a nice question. The seven hospitals that have the high volume, I think it would be safe to say they all have residents. So this could be a major factor here.

DR. JOHN F. STREMPLE (Pittsburgh, Pennsylvania): Thank you for the opportunity of reviewing your manuscript. Dr. J. Bradley Aust and I have been working on a VA database for about 13 years. I published postoperative mortality and morbidity outcomes of over a million patients using hospital discharge summary databases, both nonfederal and federal (VA) sector.

It was obvious that the hospital discharge database has problems, especially in the VA. We found in two different coding audits that there was about a 30% coding error rate in the VA. In your manuscript, you talked about peer review coding audits. I wonder, do you have any data on the Maryland database coding error rate you used as to the result of coding audits in regard to your conclusions?

My concern goes along with another part of your manuscript which showed your group of patients with a mean age of 69 but a very low comorbidity index of 0.42. This again speaks to possibly not capturing all the comorbidities in your database hospital discharge summary.

Finally, the last question, have you looked at all at the hospital volume or surgeon volume in regard to postoperative morbidity?

DR. HARMON: Thank you, Dr. Stremple. And I congratulate you on all your papers on surgical quality in the VA.

Regarding the issue of the accuracy of the database, it is important to remember that this is a financial database. It is used for setting the rates that we can charge, and relating costs to charges. This is an extremely important database in the state of Maryland for the financial health of the hospitals. This database is audited. We compared the numbers from it to our own internal numbers for the two hospitals, Bayview and Johns Hopkins Hospital, and found excellent agreement. That is all I can say about it. There will always be errors in databases.

Regarding the comorbidity, the scores exclude the cancer itself. This makes it look very low. If you include the cancer itself, our numbers would be much higher for the comorbidity. Finally, we did not evaluate postop morbidity because it is not reported in the database.

DR. L. WILLIAM TRAVERSO (Seattle, Washington): A very nice paper, Dr. Harmon. You did not have the opportunity to comment on the caveat in this paper, and that is how to validate the database. Databases have inherent coding errors. Since this survey was completed from 1992 to 1996, hospital audits had just begun to improve their databases. What do you think the effect was on your paper's conclusions with the usual 10% coding errors? That is the first question.

Number 2, you have shown nicely that at a high hospital volume center, middle volume surgeons can achieve fairly good results for colon and rectal resections. Since a small number of surgeons are probably doing the rectal cancers, have you thrown those out and relooked at just the colon database? The complexity of rectal operations could affect your outcomes. For instance, Dr. Cameron's report on Whipple procedures shows that even a low-volume surgeon doing Whipples in a high-volume hospital can achieve fairly good results. Therefore, there is a third variable here: the complexity, the hospital volume, and the surgeon volume. To put all those three together requires a huge database that you have. And I wondered if you had eliminated the rectal cancers?

DR. HARMON: I have said what I can about the database in answering Dr. Stremple. It is true that 10% errors are quoted but that was prior to some major revisions in the procedures. I would agree with the coding and auditing. Complex interactions definitely are seen between surgeon volume and hospital volume in achieving results.

DR. FRANK R. LEWIS (Detroit, Michigan): I have a question that goes to the analysis of the data. It would appear that it is much more likely that high-volume surgeons operate in high-volume hospitals and *vice versa*. Although you showed results from the high-volume hospital, low-volume surgeon, et cetera, I didn't see the numbers of patients in those groups. If in fact most patients fall along the diagonal with high-high, low-low correlation, then the real variable is surgeon volume, and the apparent influence of hospital volume may be invalid. Did you do any sort of a further analysis of variance for those two variables, or any other discriminant analysis that would allow those two variables to be separated, since I would guess there would be a very high correlation between them?

The second question relates to the low-volume surgeons. Was it possible to analyze whether the spread of mortality in the low-volume surgeons was uniform or whether there were low-volume surgeons who had consistently low mortality and other low-volume surgeons who were consistently high? This would separate whether the numbers *per se* are the determining variable or whether other surgeon characteristics are important.

DR. HARMON: That is a very thoughtful question. The low-volume surgeons were only doing a few cases per year; some of them were doing no cases, of course, during a given year. So they weren't spreading their cases around. The low-volume surgeons are likely to be operating at just one hospital—it is not really an issue for them. The high-volume surgeons, though, can spread their work around. Somebody who is doing 20 cases can do some in a little hospital, some in a big hospital. And it was our conclusion that those surgeons got good results whether they were in high-, medium-, or low-volume hospitals. We have not been able to precisely link the surgeon to the hospital using this database. It is an area we want to look at further.